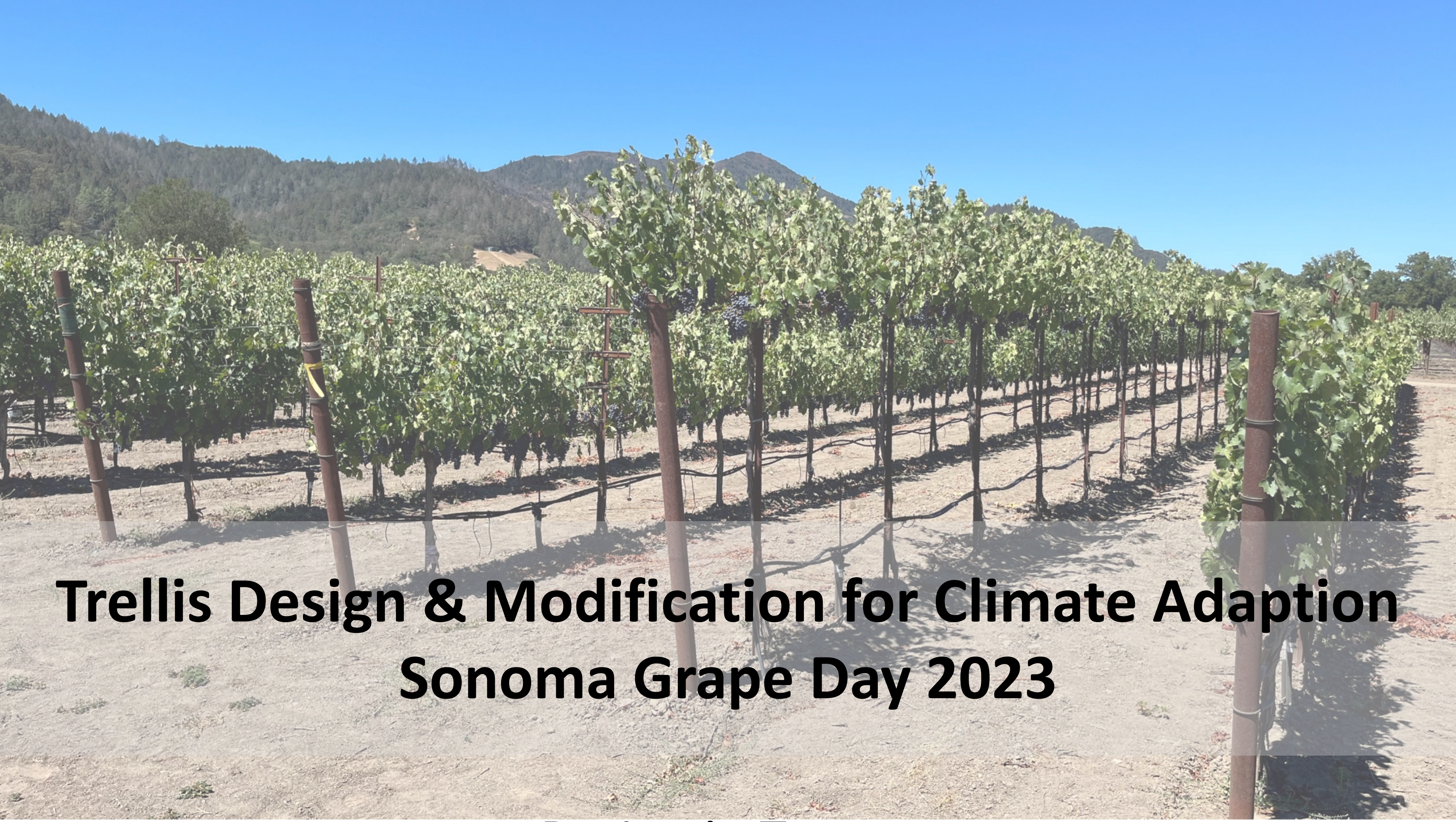

Trellis Design & Modification for Climate Adaption
Sonoma Grape Day 2023

Dr. Justin Tanner

UCCE Viticulture Advisor -San Joaquin and Stanislaus Counties

UCCE University *of* California Agriculture and Natural Resources Cooperative Extension

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Adapting wine grape production to climate change through canopy architecture manipulation and irrigation in warm climates

Runze Yu[1†], Nazareth Torres[1†], Justin D. Tanner[1], Sean M. Kacur[1], Lauren E. Marigliano[1], Maria Zumkeller[1], Joseph Chris Gilmer[1], Gregory A. Gambetta[2] and Sahap Kaan Kurtural[1*]

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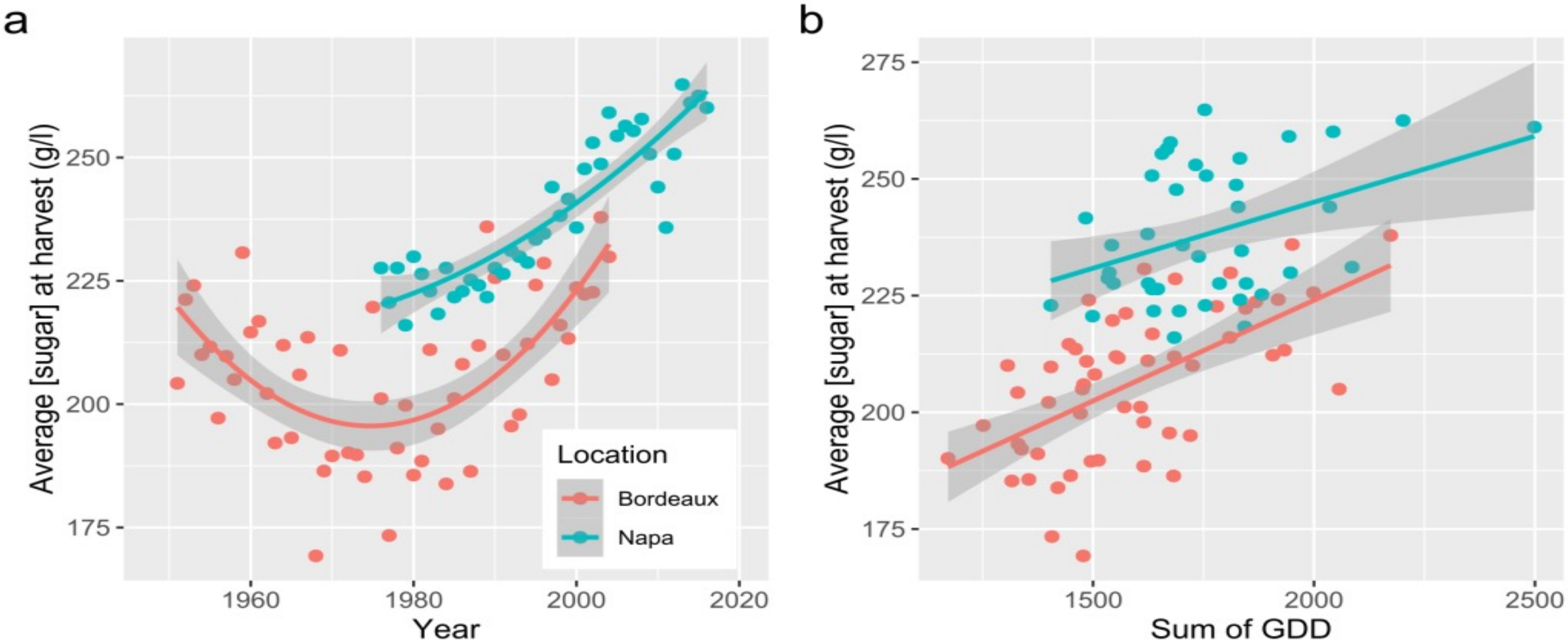
Climate change and wine grape production



Gambetta and Kurtural, 2021 Oeno-One

Warming trend in many wine producing regions

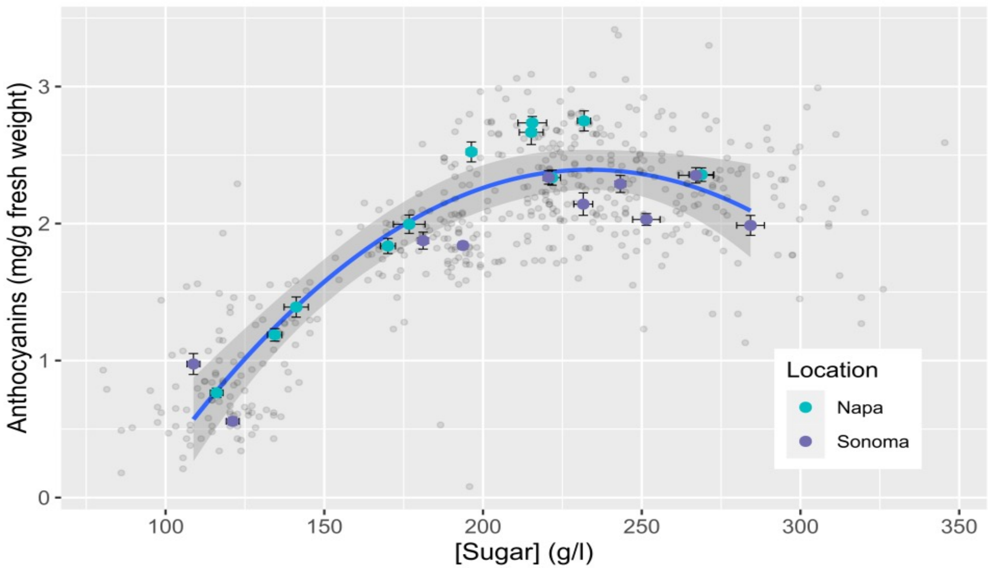
Increase in Brix at harvest correlated with increase in GDD

Climate change and wine grape production

Increase in berry sugar content decouples from anthocyanin due to degradation

More intense and frequent heat waves predicted in climate projections (Wild 2016)

Damage to grapes from overexposure will inevitably increase in the coming decades



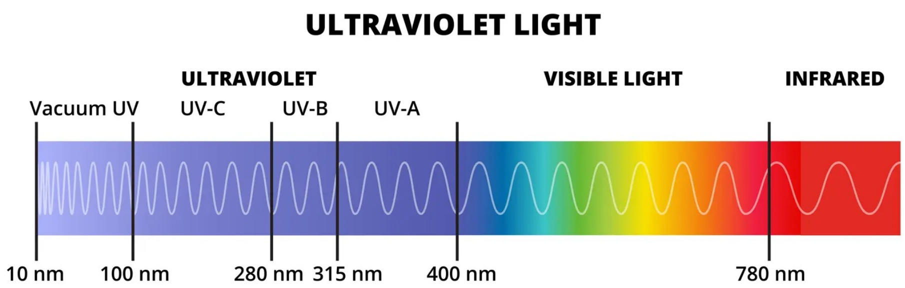
Gambetta and Kurtural, 2021
Oeno-One

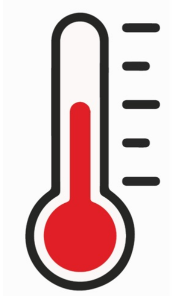
University of California
Agriculture and Natural Resources
Cooperative Extension

Overexposure of berry clusters

Results from **a combination** of excessive exposure to:

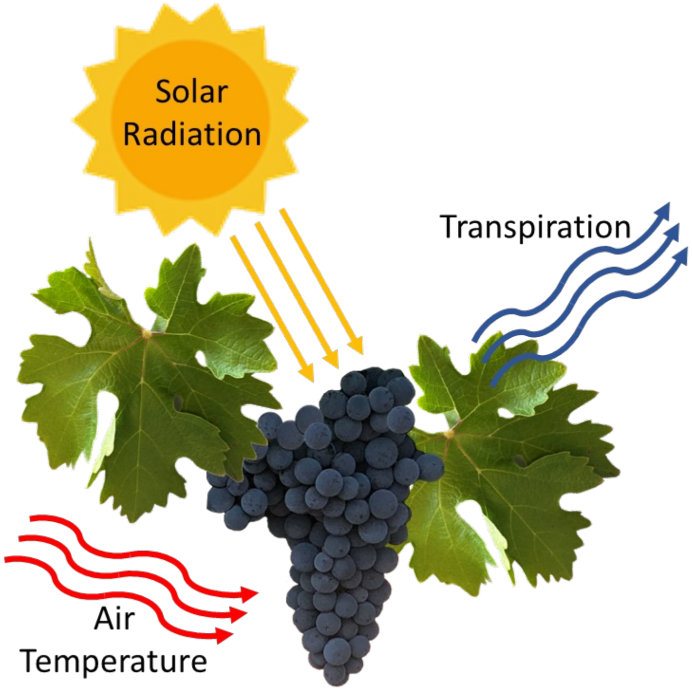
High **light** intensity + **UV** radiation + **Temperature**

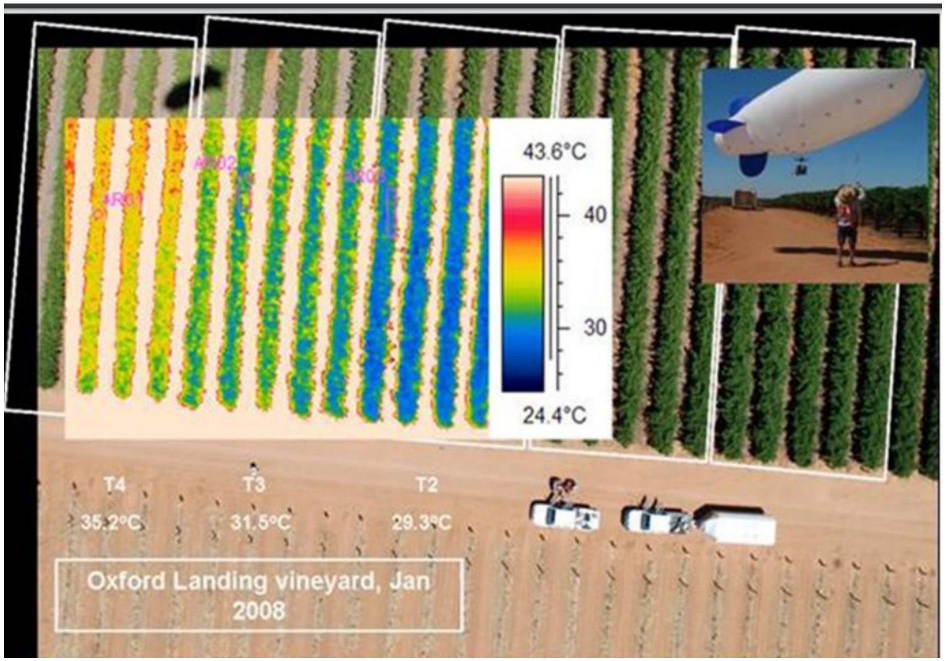




Krasnow et al. 2010

Other stress factors increase severity of overexposure: ex. **water stress**



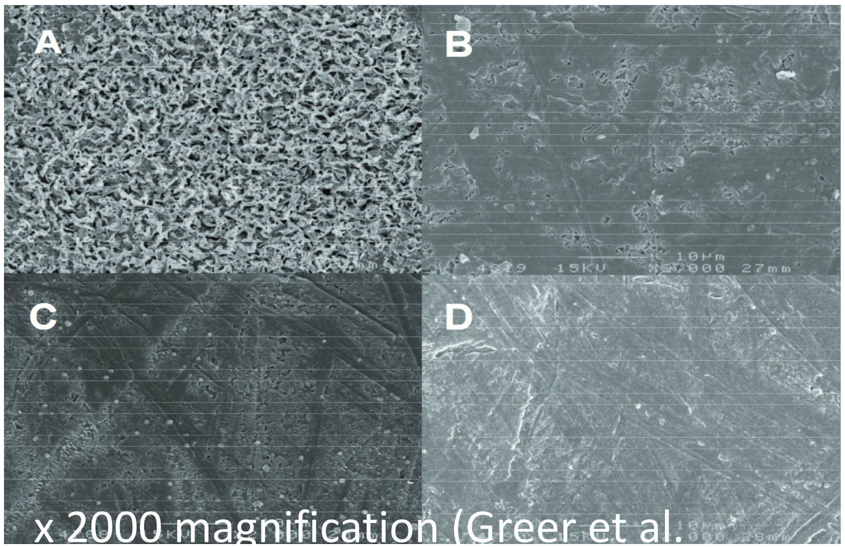


Thomas et al. 2014

Effects on fruit quality

Degradation of **berry skin waxes** leads to

- higher water **permeability**
- **dehydration** of berries/ **loss of yield**
- concentration of sugars



x 2000 magnification (Greer et al.

Degradation of **flavonoids** results in

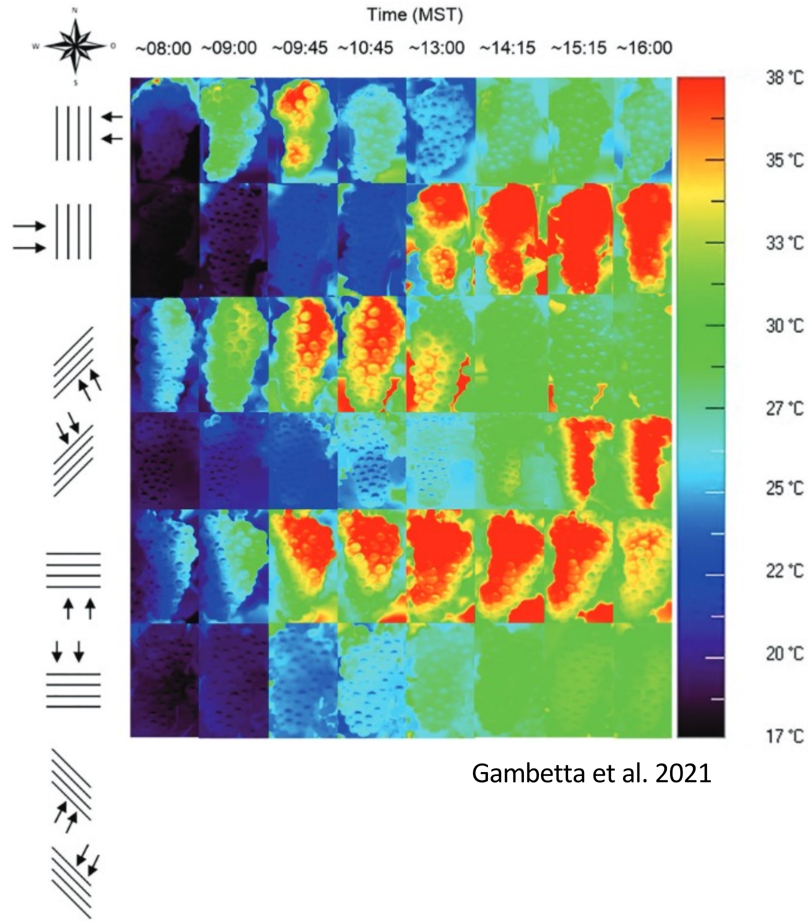
- **Reduced fruit quality**
  - poor color
  - Reduced aging potential

Martínez-Lüscher et al. 2020

(A)Control - no sunburn; (B) slight sunburn; (C) moderate sunburn; (D) severe sunburn

Row orientation – overexposure risk

Row Direction	Exposure (ratio)	Sunburn risk
N-S	Even (1:1)	Very high (west side)
NE-SW	Somewhat uneven (2:1)	Moderate (NW)
E-W	Maximum uneven (4:1)	High (south side)
NW-SE	Somewhat uneven (2:1)	Extremely high(SW side)



Gambetta et al. 2021

Mitigating overexposure

Shade nets (Martínez-Lüscher et al. 2020)

Photo selective panels

Photo selective shade films (Marigliano et al. 2022)

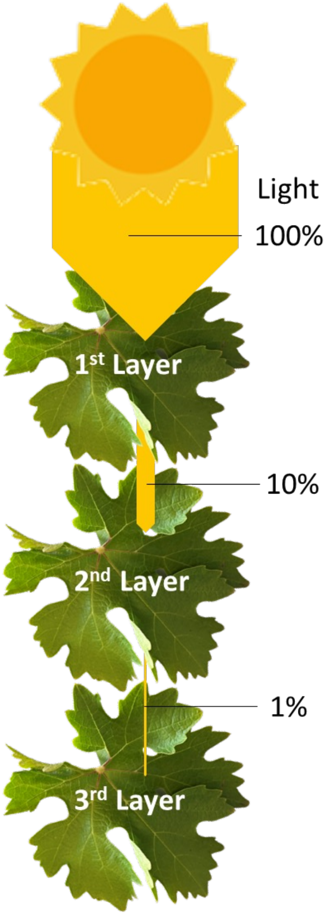
Could trellis design mitigate overexposure?

- Trellis choice influences:
  - Canopy architecture (shoot orientation, openness, density and active leaf area distribution)
  - Microclimate of canopy interior (cluster light exposure, temperature and humidity)

Single high wire

VSP60

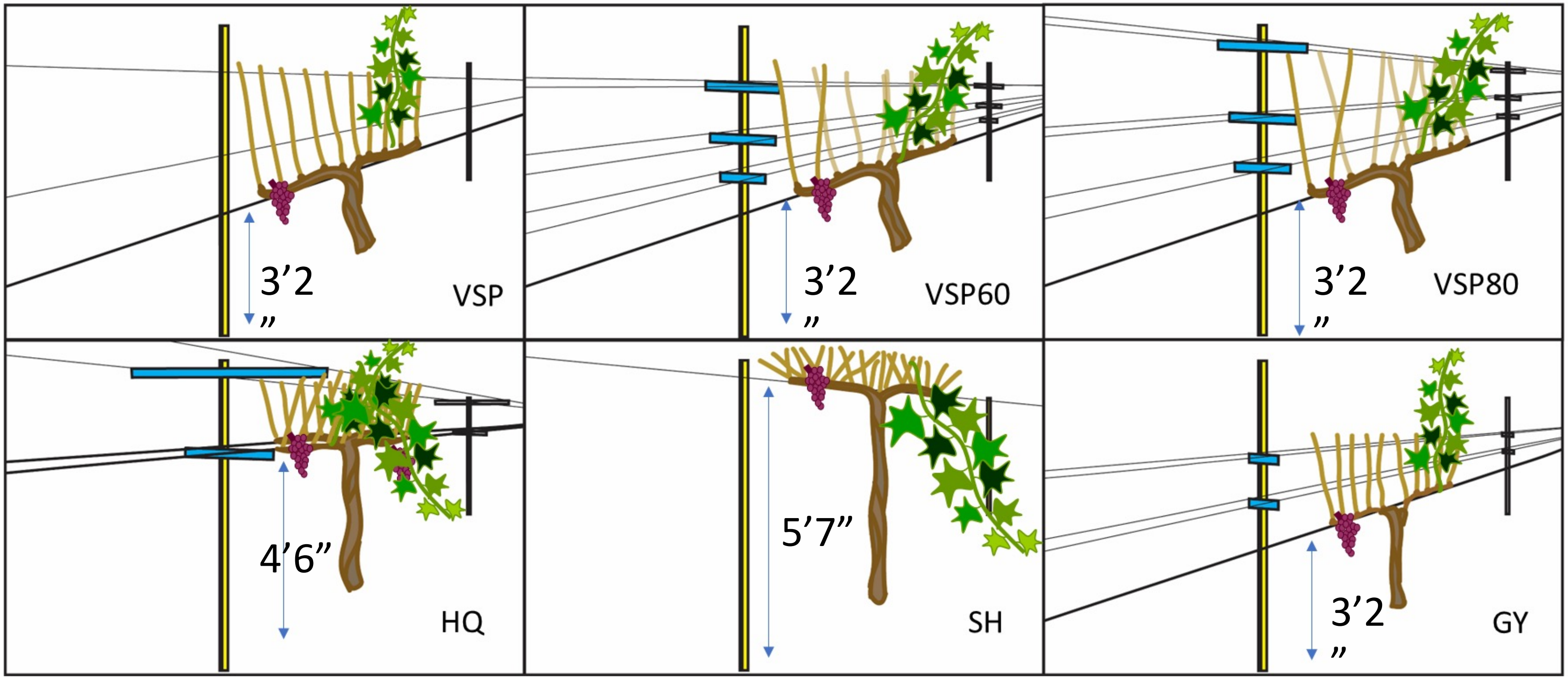
High-Quad



Experimental conditions

- 2-year study - 2020 & 2021,
- Cabernet Sauvignon /3309C rootstock (V. riparia × V. rupestris) 2016 planting
- 5 ft x 7 ft spacing (vine x row), row orientation NW-SE

Trellis systems



Trellis Systems: Vertical Shoot Position (**VSP**), Vertical Shoot Position at 60^{o} (**VSP60**), Vertical Shoot Position at 80^{o} (**VSP80**), High Quadrilateral (**HQ**), and Single High Wire (**SH**), Guyot (**GY**)

Canopy management

VSPs and **HQ** - Spur pruned to 2 buds and balanced to 25 shoots (VSPs) after bud break, 50 shoots for HQ

GY - Cane-pruned to 2 canes (12 nodes each) with 2 renewal spurs

SH - Mechanically box pruned to ~4-inch spurs and shoots thinned by 30% at ~16-inch shoot length

No leaf or **cluster removal** conducted

Irrigation treatments

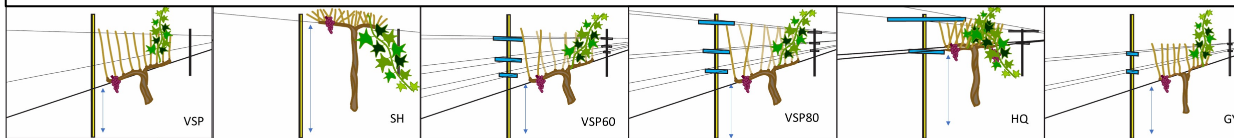
$$ET_c = ET_o \times K_c$$

- **ET_o** – data from CIMIS (station #77 Oakville)
- K_c calculated using shade cast method (Williams and Ayars 2005)

- Irrigation levels: **25%, 50%** and **100% ET_c**
  - Supplied using 1L/h, 2L/h or 4L/h drip emitters (x2)
- Duration of irrigation based on 100% ET_c

Experimental layout

- Split block experimental design
- 6 trellis systems, one in each row
- 3 irrigation levels within each row
- 18 treatment combinations per block
- 4 replicated blocks



Row 1	Row 2	Row 3	Row 4	Row 5	Row 6
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
3	4	9	10	15	16
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
2	5	8	11	14	17
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
1	6	7	12	13	18
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
VSP	SH	VSP60	VSP80	HQ	GY
Block I					

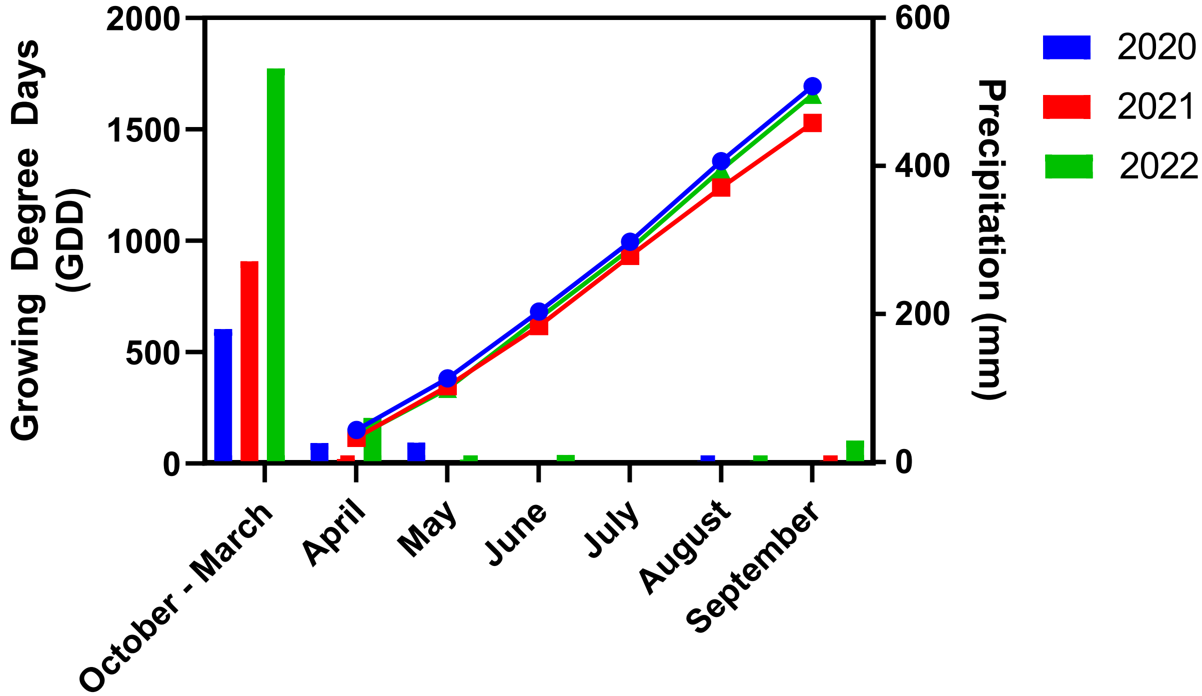
ETc	
(blue)	100%
(red)	50%
(yellow)	25%

ETc

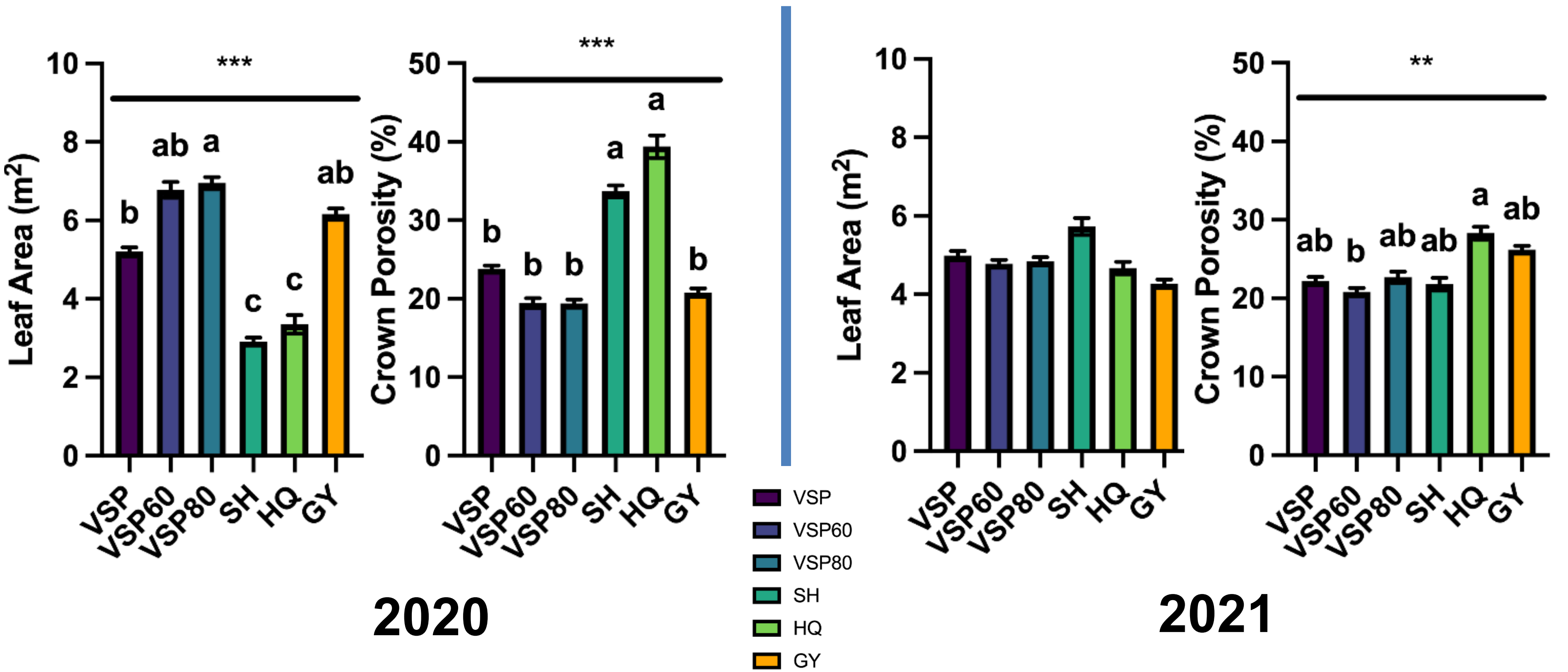
100%	(blue)
50%	(red)
25%	(yellow)

Block I						Block II						Block III						Block IV					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
3	4	9	10	15	16	21	22	27	28	33	34	39	40	45	46	51	52	57	58	63	64	69	70
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
2	5	8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
1	6	7	12	13	18	19	24	25	30	31	36	37	42	43	48	49	54	55	60	61	66	67	72
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
VSP	SH	VSP60	VSP80	HQ	GY	GY	VSP	SH	VSP80	VSP60	HQ	HQ	VSP	VSP60	SH	GY	VSP80	SH	VSP	HQ	VSP60	VSP80	GY
Block I						Block II						Block III						Block IV					

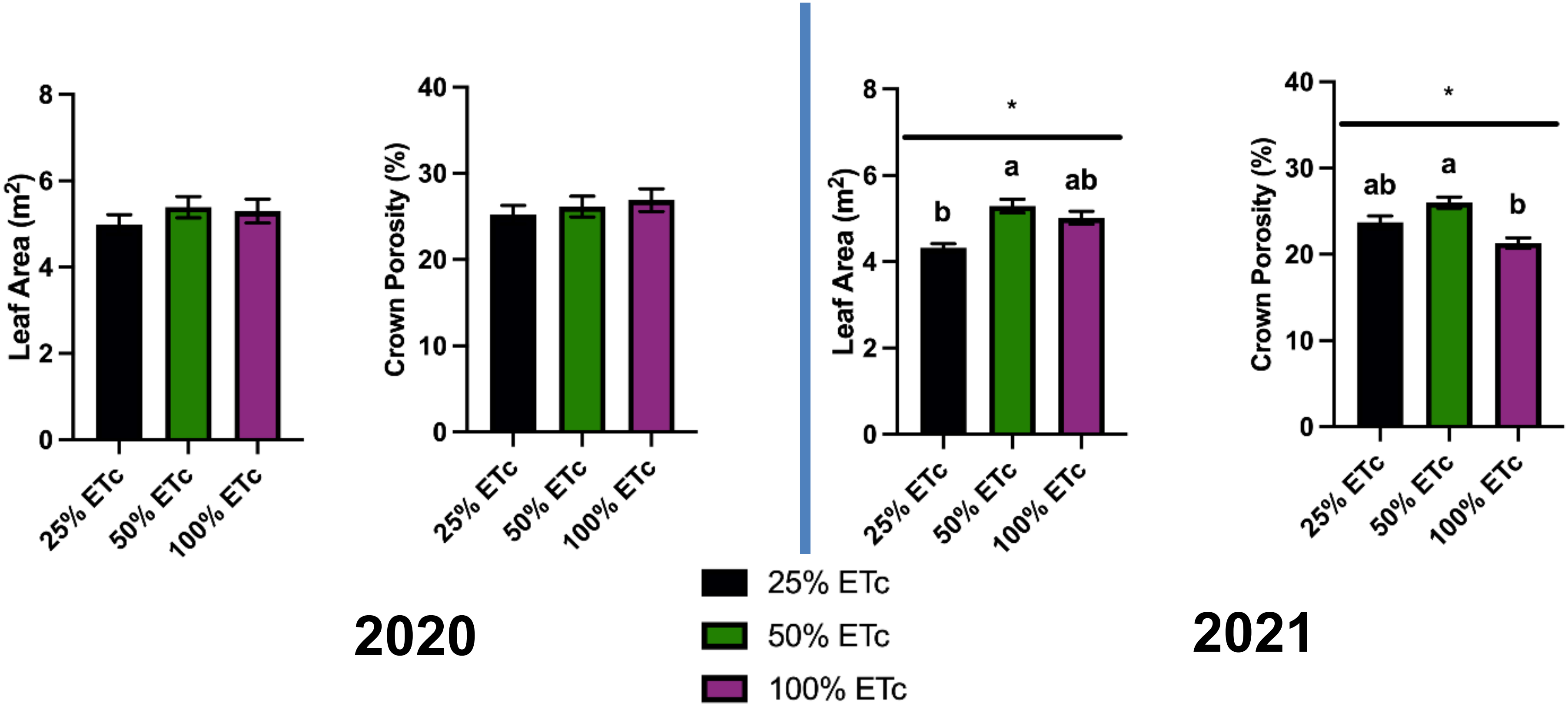
Weather at UC Oakville Station



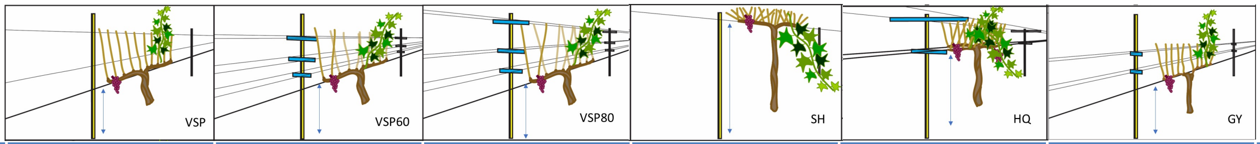
Canopy architecture - trellis



Canopy architecture - irrigation



Yield

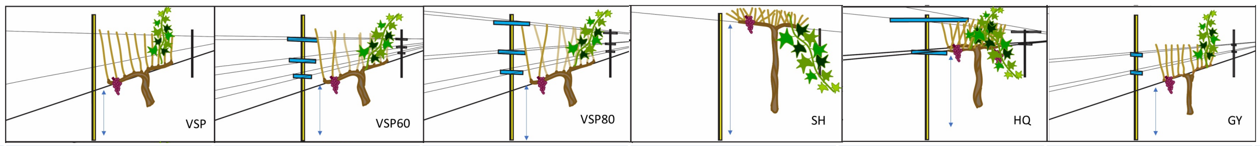


Tons/Acre	VSP	VSP60	VSP80	SH	HQ	GY	p value
2020	5.86ab	5.96ab	4.89b	6.46a	4.89b	5.31b	*
2021	9.37	10.25	9.00	11.25	14.37	9.21	ns

Tons/Acre	25% ET_c	50% ET_c	100% ET_c	p value
2020	4.65b	5.75a	6.29a	**
2021	8.41b	11.91a	11.27a	.

[a] ANOVA to compare data (p value indicated); Letters within columns indicate significant mean separation according to Duncan's multiple range test at p value < 0.1, where "."; p value < 0.05, where "*": p value < 0.05; "**": p value < 0.001, "***": p value < 0.0001. [b] Abbreviations: VSP: vertical shoot positioned; VSP 60: vertical shoot positioned 60° ; VSP 80: vertical shoot positioned 80°; SH: single high wire; HQ: high quadralateral;

Berry weight (g)

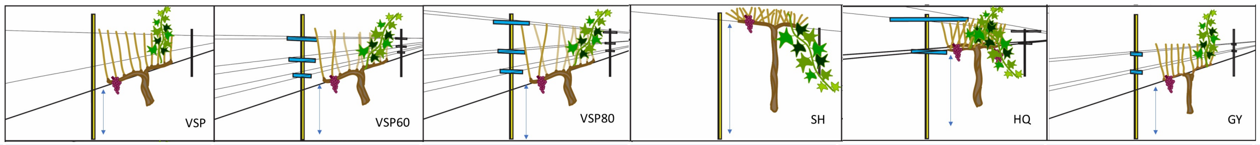


	VSP	VSP60	VSP80	SH	HQ	GY	p value
2020	0.97a	1.00a	1.01a	0.86b	0.87b	0.97a	**
2021	1.00a	1.03a	1.03a	0.88ab	0.83b	1.03a	**

	25% Et_c	50% Et_c	100% Et_c	p value
2020	0.83c	0.96b	1.05a	***
2021	0.88b	0.94b	1.07a	***

[a] ANOVA to compare data (*p* value indicated); Letters within columns indicate significant mean separation according to Duncan's multiple range test at *p* value < 0.1, where "."; *p* value < 0.05, where "*": *p* value < 0.05; "**": *p* value < 0.001, "***": *p* value < 0.0001. [b] Abbreviations: VSP: vertical shoot positioned; VSP 60: vertical shoot positioned 60° ; VSP 80: vertical shoot positioned 80°; SH: single high wire; HQ: high quadralateral; compounds were expressed in the unit of mg per g of berry fresh weight.

Cluster number

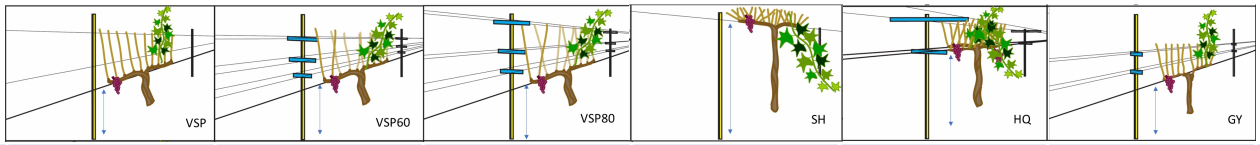


	VSP	VSP60	VSP80	SH	HQ	GY	p value
2020	62.97a	32.39bc	30.36c	62.97a	38.11b	27.67c	***
2021	45.51b	48.86b	44.50b	88.28a	82.61a	39.86b	***

	25% Et_c	50% Et_c	100% Et_c	p value
2020	35.96	38.04	38.07	ns
2021	55.94	56.97	62.04	ns

[a] ANOVA to compare data (*p* value indicated); Letters within columns indicate significant mean separation according to Duncan's multiple range test at *p* value < 0.1, where "."; *p* value < 0.05, where "*": *p* value < 0.05; "**": *p* value < 0.001, "***": *p* value < 0.0001. [b] Abbreviations: VSP: vertical shoot positioned; VSP 60: vertical shoot positioned 60° ; VSP 80: vertical shoot positioned 80°; SH: single high wire; HQ: high quadralateral; compounds were expressed in the unit of mg per g of berry fresh weight.

Anthocyanins in berry skins

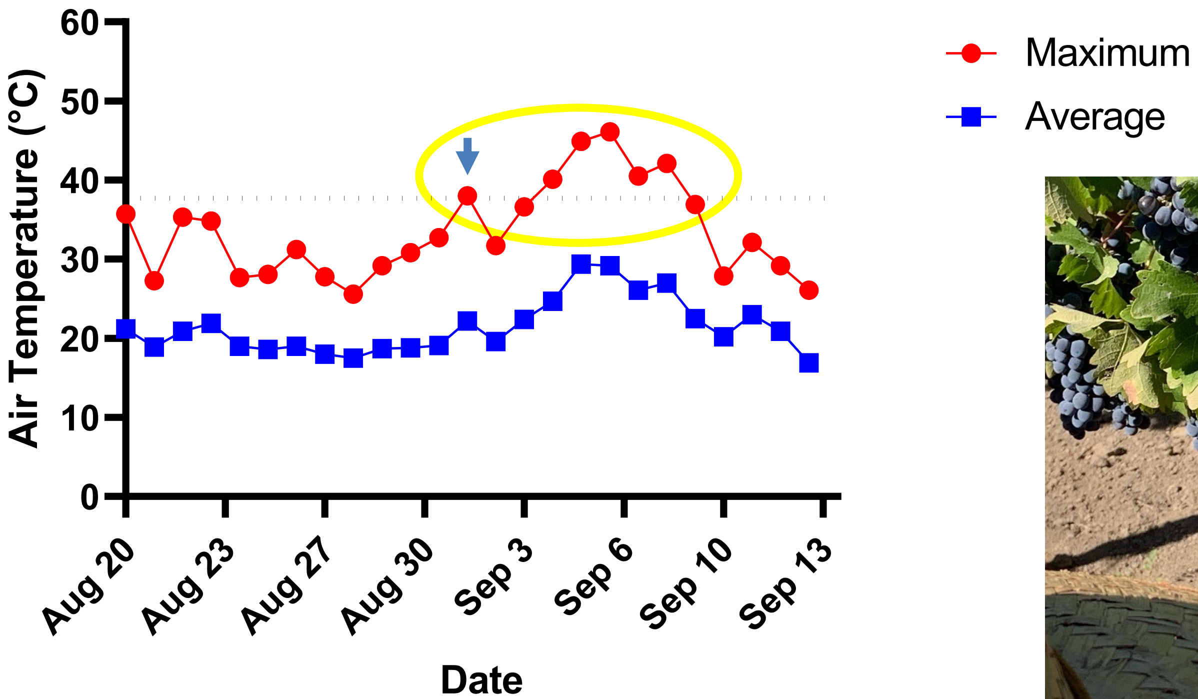


Total Anthocyanins	VSP	VSP60	VSP80	SH	HQ	GY	p value
2020	30.09b	30.87b	34.52b	44.89a	32.73b	32.27b	***
2021	31.4cd	32.8cd	35.17c	51.80a	45.22b	28.46d	***

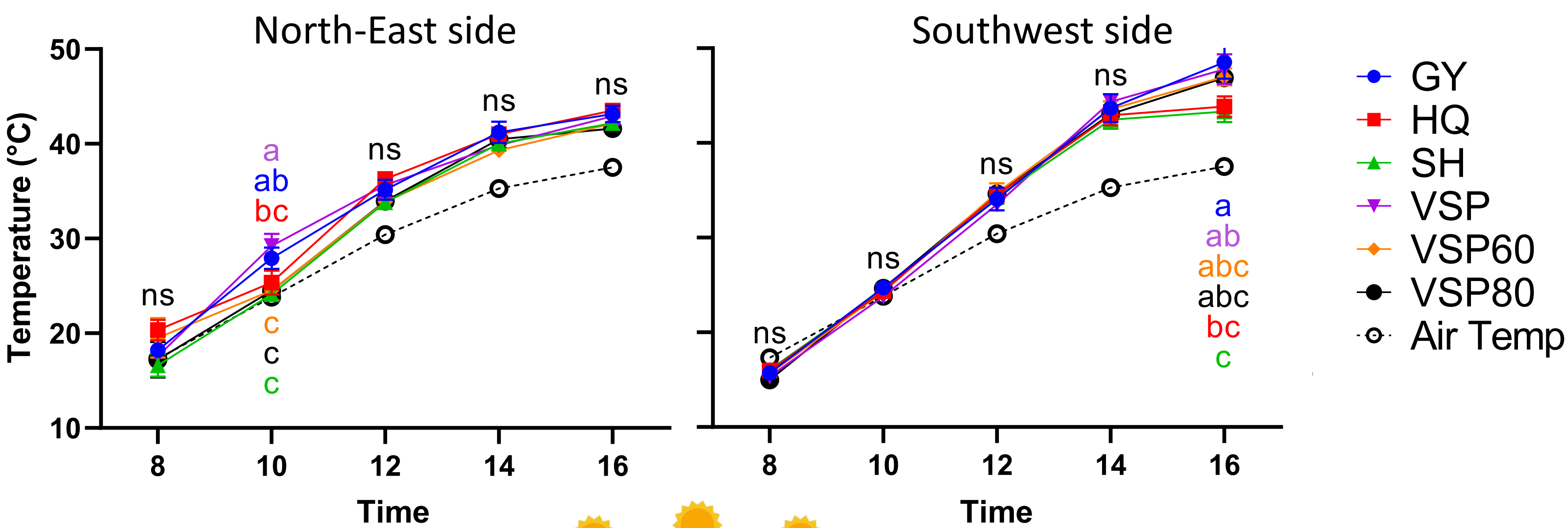
Total Anthocyanins	25% ET_c	50% ET_c	100% ET_c	p value
2020	34.91	35.97	31.81	ns
2021	39.89	38.73	33.85	ns

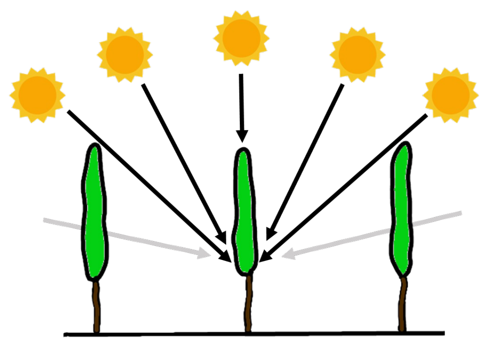
[a] ANOVA to compare data (*p* value indicated); Letters within columns indicate significant mean separation according to Duncan's multiple range test at *p* value < 0.1, where "."; *p* value < 0.05, where "*": *p* value < 0.05; "**": *p* value < 0.001, "***": *p* value < 0.0001. [b] Abbreviations: VSP: vertical shoot positioned; VSP 60: vertical shoot positioned 60° ; VSP 80: vertical shoot positioned 80°; SH: single high wire; HQ: high quadralateral; compounds were expressed in the unit of mg per g of berry fresh weight.

Heat wave – 2022 preharvest



Cluster temperatures - Sept. 1, 2022

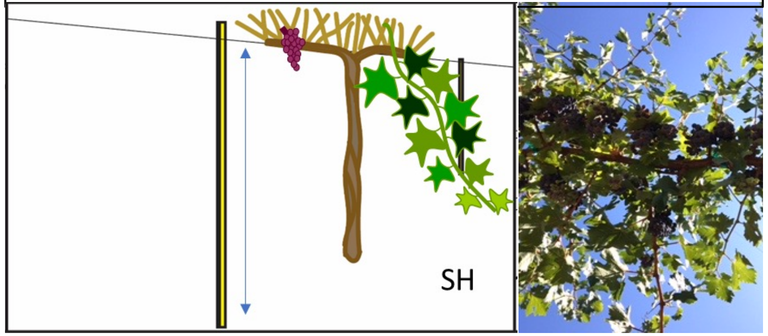




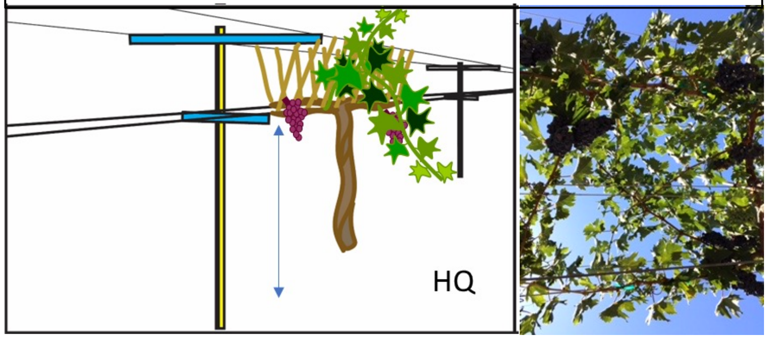
Study insights - trellis

- **SH** and **HQ** trellis systems promote **yield** and **quality** in a hot climate
    - **Greater anthocyanin** production in berry skins, **more advanced berry ripening** and **less chemical degradation**
- **VSP** and **GY** systems produced canopies which allowed for berry **overexposure** and **anthocyanin degradation** in a hot climate

Single High Wire



High-Quad

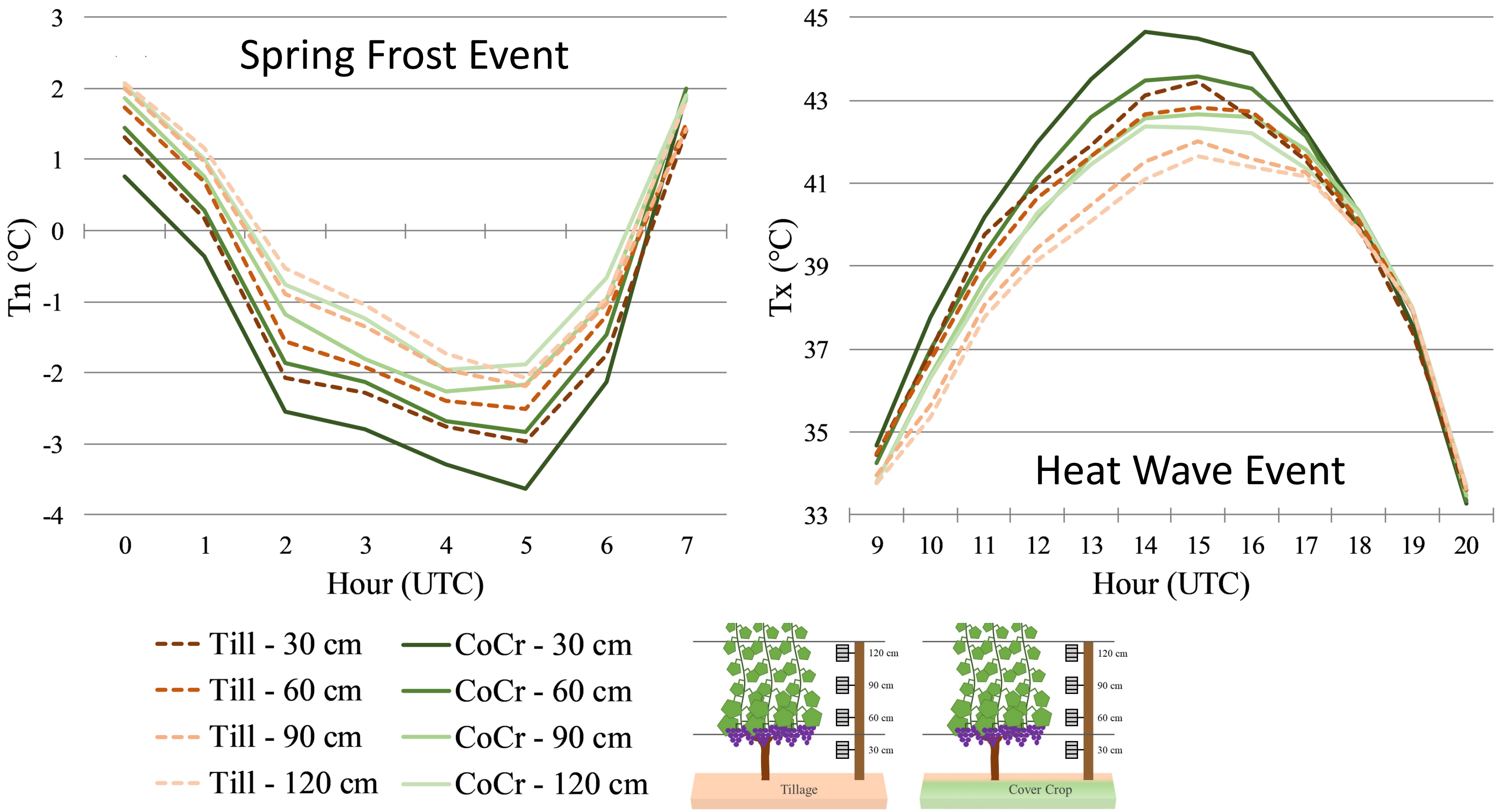


Study insights - irrigation

- **Increased** irrigation (50 and 100% ET_c) improves plant water status resulting in **heavier berries**, **clusters**, and **increased yield**

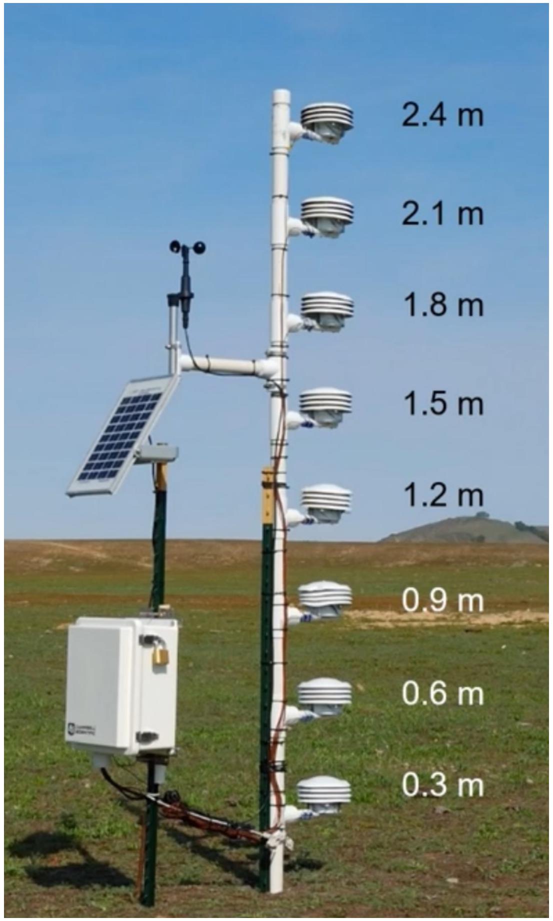
- **Decreased** irrigation (25% ET_c) increases **brix** at harvest (2020) and produces **higher flavonoids** (2021)

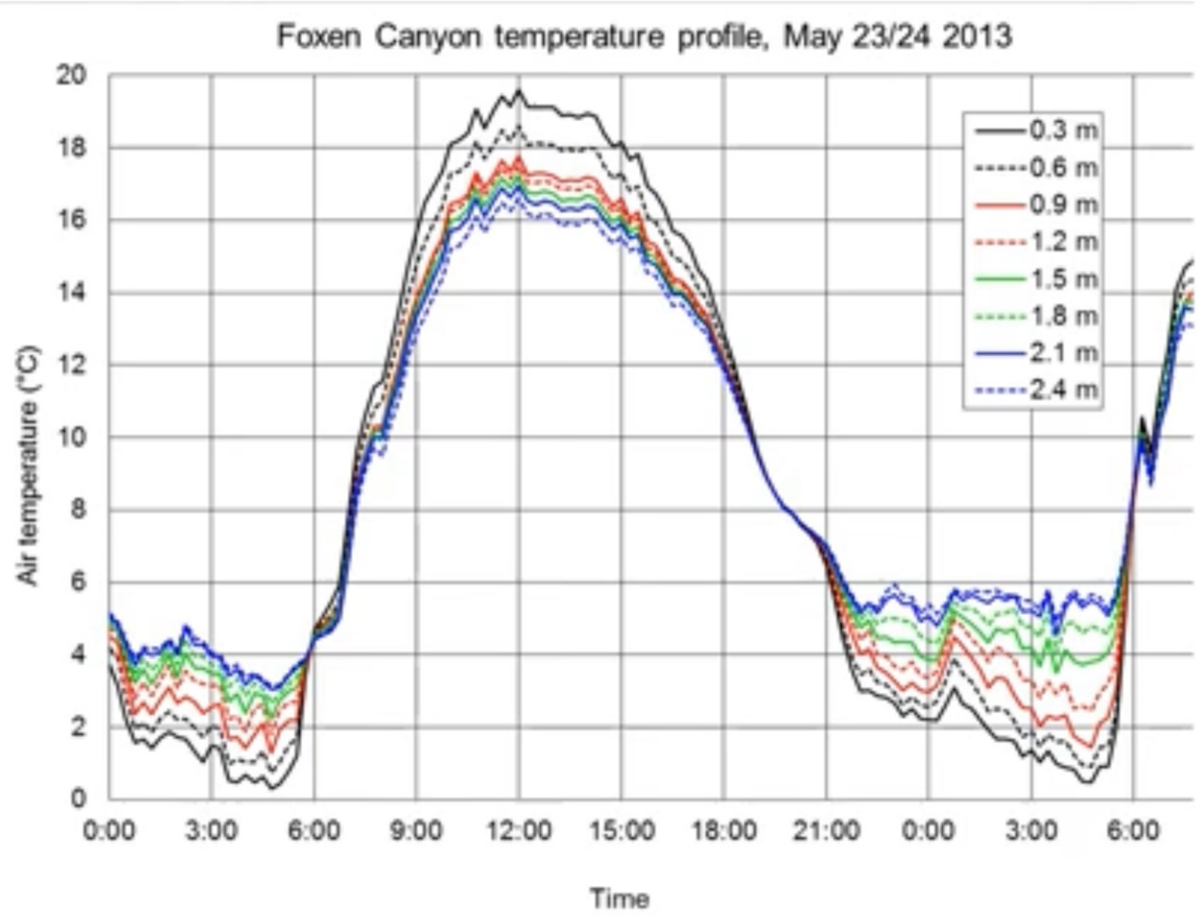
Height effect on temperature extremes



de Rességuier, Laure, et al. 2023

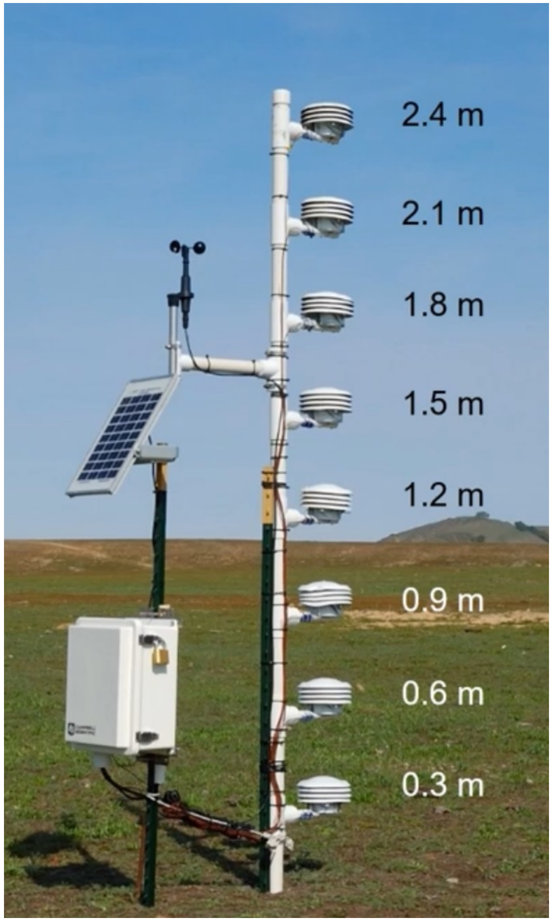
Air temperature varies by height

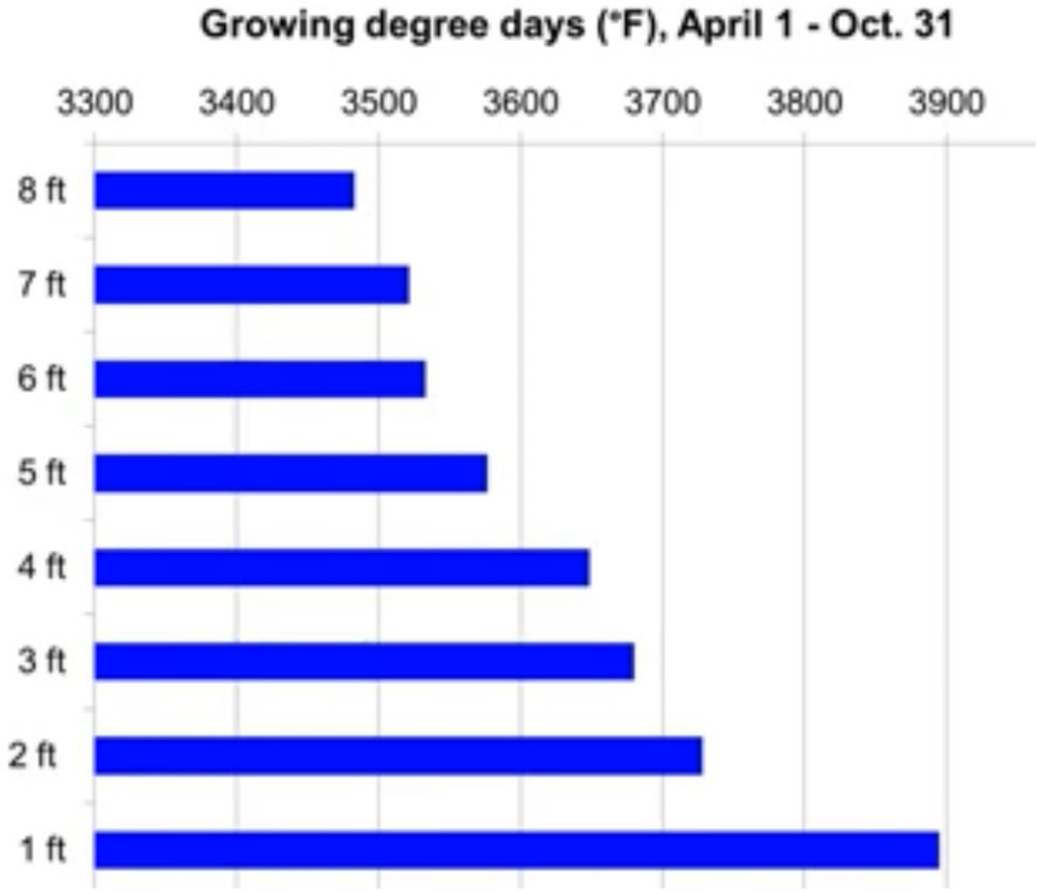




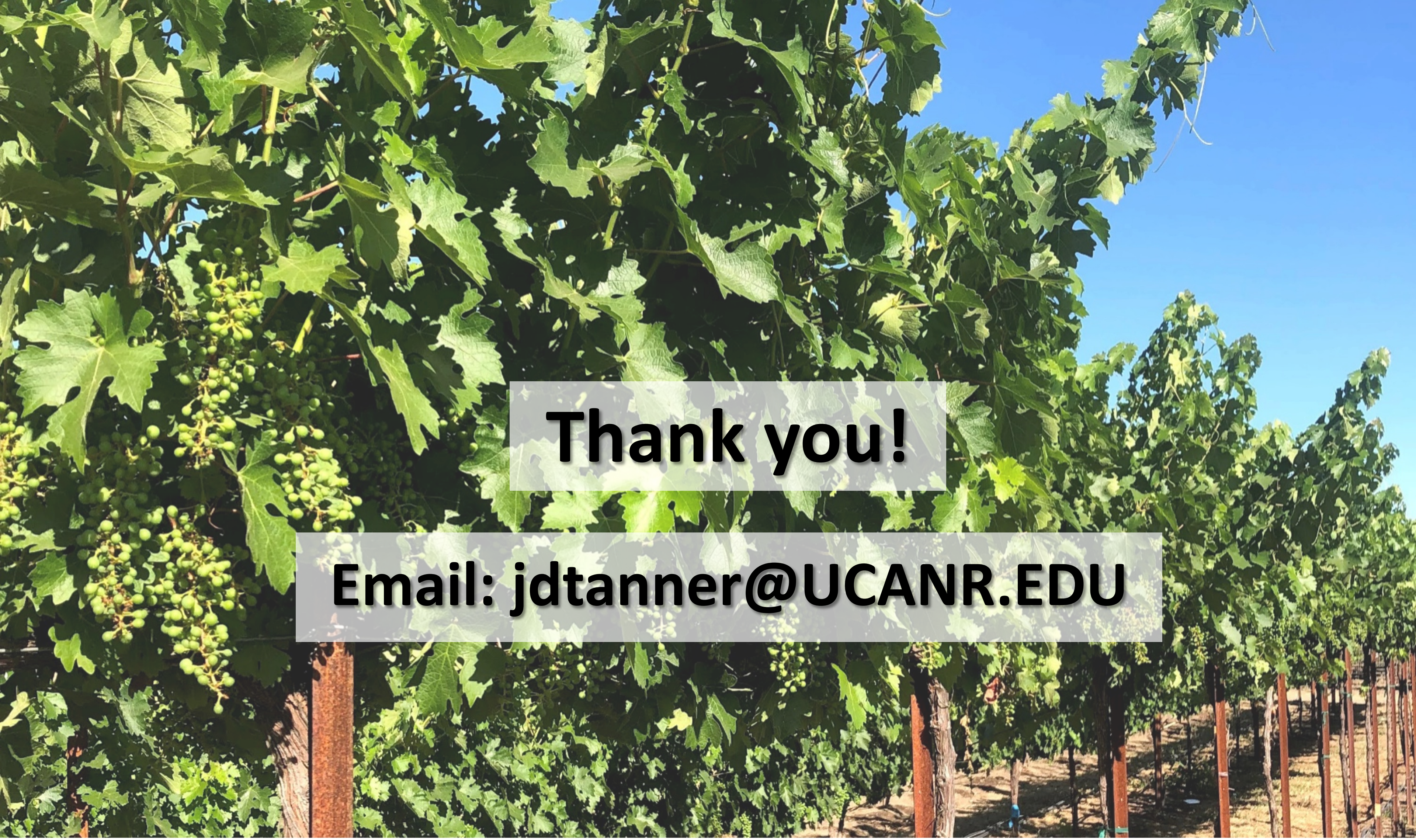
https://cesanluisobispo.ucanr.edu/viticulture

Seasonal temperature accumulation





https://cesanluisobispo.ucanr.edu/viticulture



Thank you!

Email: jdtanner@UCANR.EDU